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DESCRIPTION

STEEL FOR EXHAUST GAS PROCESSING EQUIPMENT AND EXHAUST GAS DUCT EXCELLENT IN WEAR RESISTANCE OR WEAR RESISTANCE AND GAS CUTTING PROPERTY

TECHNICAL FIELD

The present invention relates to a steel for exhaust gas processing equipment and to an exhaust gas duct exhibiting a excellent durability and excellent in constructability, repairability, and economy in an exhaust gas environment of a converter and an electric melting furnace in refining of a ferrous metal or other metal.

BACKGROUND ART

The prior art will be explained with reference to the example of a refining furnace for steel production a ferrous metal (converter, electric furnace, etc.).

As exhaust gas out of a metal refining furnace contains corrosive gas ingredients or metal dust, the passage of the exhaust gas in exhaust gas equipment undergoes severe wear. In general, the exhaust gas reaches a temperature of 1200°C. In some furnaces, combustible gas is burnt in the combustion tower before being passed through the exhaust gas equipment.

In general, an exhaust gas duct formed into a double-wall tube structure made of welded carbon steel sheets. Exhaust gas runs through the inside tube, and cooling water runs between the inside tube and the outside tube. Alternatively, steel tubes are arranged at the inside surface of a duct to create a water cooling tube panel, and cooling water runs through their insides. These will be called "hereinafter collectively exhaust gas water cooling ducts".

In recent years, wear of exhaust gas water cooling ducts have been more remarkable. Up to the early 1990s, five years or more of durability had been obtained by

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carbon steel inside tubes of a thickness of 9 mm. But recently, while the thickness has been increased to 12 mm, many wear incidents are observed within a half year to one year of service. Routine repair or replacement work has therefore been the practice. Further, even in converter exhaust gas (OG) processing systems, recently the endurance life of the exhaust gas water cooling ducts has shortened to half or less compared with the past.

For example, the maximum wear rate of perforated parts has reached several mm to 20 mm/year in conventional steel.

The wear is believed to be caused by abrasion due to collision by solid grains, molten salt corrosion due to dust, wet corrosion accompanying the formation of concentrated electrolytes due to absorption of moisture etc., but the most dominant process of wear among these factors has not been determined much at all.

In the prior art for preventing wear of an exhaust gas water cooling duct, changing the material of the surface contacting the exhaust gas so as to secure durability has been proposed, which is classified into modifying the surface contacting the exhaust gas and adopting a suitable material for the duct themselves.

Techniques for modifying the surface contacting the exhaust gas include, for example, 1) lining the inside with heat resistant, refractory, 2) lining the inside with an inorganic caster, 3) forming a thick melt sprayed layer, 4) employing clad steel having a high alloy steel as its surface layer, some of whom have already been proposed.

Examples include melt spray buildup with a stainless steel-based alloy as disclosed in Japanese Patent Publication (B) No. 4-80089, forming a melt sprayed coating layer of an alloy of ingredients forming an oxide at 800°C as disclosed in Japanese Patent No. 2565727, and coating by a self melting melt sprayed alloy such as a Ni-Cr-Mo-B system as disclosed in Japanese Patent

Publication (A) No. 2003-231909 (metal coating forming alloy layer by a base material and melt sprayed metal).

Further, as for adopting a suitable material for the duct themselves, replacing carbon steel with a structural material excellent in durability, such as SUS310S or other heat resistant stainless steel, may be easily considered.

Measures such as lining with brick, melt spraying a metal, lining with an inorganic material, and cladding by an alloy all result in extremely high material and construction costs in exhaust gas ducts for which bare carbon steel has previously been used. In addition, their unavoidable differences in heat expansion coefficient with carbon steel result in a difficulty of securing long term bonding in an environment of a thermal cycle of a high temperature of about 1000°C and room temperature once an hour.

Further, when employing lining with refractory or an inorganic material, there are the problems of 1) the lower cooling rate of the exhaust gas and therefore the need for increasing the length of the exhaust gas duct for feeding exhaust gas below a predetermined temperature to the dust collection system, 2) the inability to sufficiently suppress dioxins when the cooling rate becomes too low and therefore the need for further measures against the production of dioxins, 3) the increase in weight of the exhaust gas ducts, etc.

When replacing carbon steel with stainless steel or high alloy steel, there is the problem of an extremely high cost of materials and construction. In particular, in the case of stainless steel, there is the problem that cutting using acetylene gas etc. as widely practiced in on-site construction was difficult. Further, even with SUS316L, SUS310S, or other stainless steel cannot secure durability economically expected.

Therefore, a steel for exhaust gas processing equipment excellent in constructability and durability

has been sought. Specifically, as explained above, in conventional steel, the maximum wear rate of perforated parts has reached several mm to 20 mm/year, so a steel for exhaust gas processing equipment, in particular for an exhaust gas duct, excellent in wear resistance (for example, in maximum wear rate, 2.5 mm/year or less) has been strongly waited.

Further, an exhaust gas duct using one side of the carbon steel as the surface contacting the exhaust gas (gas contact surface) and the remaining side as the coolant surface is extremely excellent in material costs, constructability, repairability, and economy. Therefore, an exhaust gas duct equivalent to a carbon steel exhaust gas duct in constructability and repairability, remarkably excellent in durability of the gas contact surface, and economically feasible as well has been strongly sought.

SUMMARY OF THE INVENTION

The present invention was made to overcome the above problems and has as its object to provide a steel for exhaust gas processing equipment excellent in durability, workability, and constructability in an exhaust gas environment of a converter and electric furnace, as melting or refining equipment for steel and metal or ash melting furnace, and an exhaust gas duct made of such steel.

The inventors studied in detail the wear mechanism of water-cooled exhaust gas ducts steel melting furnaces and ash melting furnace and as a result discovered that a steel of a specific chemical composition range exhibits an excellent durability in an exhaust gas environment and provides a workability and constructability equivalent to carbon steel.

That is, they discovered that by controlling the alloy composition not disclosed in the prior art, a novel steel is obtained.

Further, they discovered that by using steel of the

above specific chemical composition range as the gas contact surface and combining it with specific known welding materials, an exhaust gas duct is obtained by an fabrication efficiency equivalent to that with carbon steel.

The present invention was made based on the above discovery and has as its gist the following:

(1) A steel for exhaust gas processing equipment excellent in wear resistance, containing, by mass%,

C: 0.001 to 0.2%,
Cu: 0.1 to 1%,
Ni: 0.01 to 0.5%,
Cr: 4.0 to 9.0%, and
Sb: 0.01 to 0.2% and

containing one or both of

Mo: 0.005 to 0.5% and
W: 0.005 to 0.5% and

the balance of Fe and unavoidable impurities.

(2) A steel for exhaust gas processing equipment excellent in wear resistance, containing, by mass%,

C: 0.001 to 0.2%,
Si: 0.01 to 0.5%,
Mn: 0.1 to 2%,
Cu: 0.1 to 1%,
Ni: 0.01 to 0.5%,
Cr: 4.0 to 6.0%,
Sb: 0.01 to 0.2%,
P: 0.05% or less, and
S: 0.005 to 0.02% and

containing one or both of

Mo: 0.005 to 0.5% and
W: 0.005 to 0.5% and

the balance of Fe and unavoidable impurities.

(3) A steel for exhaust gas processing equipment as set forth in (1) or (2), wherein said exhaust gas processing equipment is an exhaust gas duct.

(4) A steel for exhaust gas processing equipment

excellent in wear resistance and gas cutting property containing, by mass%,

C: 0.001 to 0.2%,

Si: 0.01 to 0.5%,

Mn: 0.1 to 2%,

Cu: 0.1 to 1%,

Ni: 0.01 to 1%,

Cr: 4.0 to 6.0%,

Sb: 0.01 to 0.2%,

Al: 0.005 to 0.5%,

P: 0.05% or less,

S: 0.005 to 0.02%, and

N: 0.008% or less and

containing one or both of

Mo: 0.005 to 0.5% and

W: 0.005 to 0.5% and

the balance of Fe and unavoidable impurities.

(5) A steel for exhaust gas processing equipment excellent in wear resistance and gas cutting property as set forth in (4) further containing, by mass%, one or more of

Nb: 0.002 to 0.2%,

V: 0.005 to 0.5%,

Ti: 0.002 to 0.2%,

Ta: 0.005 to 0.5%,

Zr: 0.005 to 0.5%, and

B: 0.0002 to 0.005% and

the balance of Fe and unavoidable impurities.

(6) A steel for exhaust gas processing equipment excellent in wear resistance and gas cutting property as set forth in (4) or (5) further containing, by mass%, one or more of

Mg: 0.0001 to 0.01%,

Ca: 0.0005 to 0.01%,

Y: 0.0001 to 0.1%,

La: 0.005 to 0.1%, and

Ce: 0.005 to 0.1% and

the balance of Fe and unavoidable impurities.

(7) A steel for exhaust gas processing equipment excellent in wear resistance and gas cutting property as set forth in any one of (4) to (6) further containing, by mass%, one or both of

Sn: 0.01 to 0.3% and

Pb: 0.01 to 0.3% and

the balance of Fe and unavoidable impurities.

(8) An exhaust gas duct wherein a gas contact surface of a passage of exhaust gas in the exhaust gas duct is comprised of steel containing, by mass%,

C: 0.001 to 0.2%,

Cu: 0.1 to 1%,

Ni: 0.01 to 0.5%,

Cr: 4.0 to 9.0%, and

Sb: 0.01 to 0.2% and

containing one or both of

Mo: 0.005 to 0.5% and

W: 0.005 to 0.5% and

the balance of Fe and unavoidable impurities, and welded together by an austenitic welding material.

(9) An exhaust gas duct wherein a gas contact surface of a passage of exhaust gas in the exhaust gas duct is comprised of a double-layer steel having as a surface layer of said steel containing, by mass%,

C: 0.001 to 0.2%,

Cu: 0.1 to 1%,

Ni: 0.01 to 0.5%,

Cr: 4.0 to 9.0%, and

Sb: 0.01 to 0.2% and

containing one or both of

Mo: 0.005 to 0.5% and

W: 0.005 to 0.5% and

the balance of Fe and unavoidable impurities, and welded together at its surface layer by an austenitic welding material.

(10) An exhaust gas duct wherein a gas contact

surface of a passage of exhaust gas in the exhaust gas duct is comprised of a steel containing, by mass%,

C: 0.001 to 0.2%,
Si: 0.01 to 0.5%,
Mn: 0.1 to 2%,
Cu: 0.1 to 1%,
Ni: 0.01 to 0.5%,
Cr: 4.0 to 6.0%,
Sb: 0.01 to 0.2%,
P: 0.05% or less, and
S: 0.005 to 0.02% and

containing one or both of

Mo: 0.005 to 0.5% and
W: 0.005 to 0.5% and

the balance of Fe and unavoidable impurities and a welding metal in a composition range of the same as said steel.

(11) An exhaust gas duct as set forth in any one of (8) to (10), wherein said exhaust gas duct is a double-wall tube type water-cooled exhaust gas duct which is comprised of a metal outside tube and metal inside tube where the inside of the inside tube is used as the passage of the exhaust gas and the gap between the outside tube and the inside tube is used as the passage of the coolant.

(12) An exhaust gas duct as set forth in any one of (8) to (10) wherein said exhaust gas duct is an exhaust gas duct where a plurality of tubes are joined and arranged at an opposite surface of the passage of the exhaust gas from the gas contact surface and has the function of circulating a coolant through said tubes.

The steel of the present invention exhibits excellent durability in an environment of exhaust gas processing equipment of a metal melting or metal refining furnace and has workability and constructability equivalent to a carbon steel.

Further, the exhaust gas duct of the present

invention exhibits an excellent durability in an exhaust gas environment of a metal melting or metal refining furnace or ash melting furnace and has an constructability, repairability, and economy equivalent to a carbon steel.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a view showing the effect of the amount of Cr on the maximum and average wear rates of steel to which Cr alone is added in an inside tube of a water-cooled duct of a steel melting electrical furnace.

FIG. 2 is a view showing the effect of composite addition of Cu, Ni, and Sb on the wear rate of 5% Cr steel in an inside tube environment of a water-cooled exhaust gas duct.

FIG. 3 is a view showing an example of the structure of a double-wall water-cooled duct.

FIG. 4 is a view showing an example of an inside tube of a double-wall water-cooled duct.

FIG. 5 is a view showing an example of the structure of a duct comprised of water-cooled panels, wherein (a) shows a cross-section of the duct and (b) shows a cross-section of a water cooling tube enlarged.

THE MOST PREFERRED EMBODIMENT

The present invention will be explained in detail. Hereinafter, the % means the mass%.

The framework of the steel of the present invention is that the composite addition of low C-Cr-Cu-Ni- (Mo, W, Mo+W)-Sb or low C-Cr-low Si-Cu-(Mo, W, Mo+W)-Sb, enables (1) excellent durability in exhaust gas processing equipment environment of a metal refining furnace and (2) simultaneous provision of a workability and constructability equivalent to ordinary steel by using together with an austenitic welding material.

Further, the framework of the present invention comprises; first that the exhaust gas duct structure has a forced cooling mechanism wherein a low C-Cr-Cu-Ni-(Mo, W, Mo+W)-Sb steel contacts the gas and the other side is

water-cooled in a passage of exhaust gas passage and a passage of a cooling medium; and second that the exhaust gas duct is fabricated by welding steel sheets having the above composition using an austenitic welding material or ferritic welding material of the same composition as the steel.

In general, the gas contact surface of exhaust gas processing equipment degrades (declines in thickness) due to the wear caused by interaction of the exhaust gas and the material. In wear, a chemical corrosion or a physical abrasion etc. compositely act. In the present invention, any phenomenon inviting a reduction in thickness of the surface of the material contacting the gas in exhaust gas processing equipment is called "wear".

Further, in the present invention, the steel is evaluated for wear resistance using the average wear rate and the maximum wear rate as indicators.

First, the effect of the alloy composition on the wear behavior will be explained. FIG. 1 shows the results of using the composition of the comparative example A3 shown in Table 1 (or Table 4) as the basic composition and changing the amount of Cr so as to investigate the effects of Cr on the average wear rate and maximum wear rate at the inside surface of an exhaust gas duct of a electric furnace for steel making. From FIG. 1, it is learned that to obtain a sufficient effect by the average wear rate, 4.0% or more of Cr has to be added.

Further, it is learned that with addition of Cr alone, the maximum wear depth is not sufficiently reduced. For this reason, in the case of steel to which 4.0% or more of Cr is added, a third element must be compositely added to improve the wear resistance.

The inventors studied the effect of compositely added elements on the wear resistance of steel containing 4.0% or more of Cr and as a result found that for improvement of the wear resistance, addition of a low level of C, Si, Cu, Ni, Mo, W, Sb, Sn, and Pb is

effective. Further, the inventors learned that by composite addition of Cu-Ni-(Mo, W, Mo+W)-Sb, a remarkable effect of improvement of the wear resistance is obtained.

FIG. 2 shows the result of investigation of the effects in the case of compositely adding Cu, Ni, Mo, and Sb to 5% Cr in a wear environment of a steel exhaust gas duct. If compositely adding Cu-Ni-Mo-Sb in a Cr-containing steel, it is learned that the maximum wear rate is reduced to 2 mm/y (year) or less and that the wear resistance is remarkably improved. That is, if even not one element of the Cu, Ni, Mo, and Sb is included, an excellent wear resistance is not obtained.

Here, in the present invention, "excellent wear resistance" specifically means, based on the fact that the comparative example shown in FIG. 2 has a maximum wear rate over 5 mm/y (year), a maximum wear rate of 5 mm/y (year) or less, preferably 3.5 mm/y (year) or less.

Next, the securing of the gas cutting property will be explained. If blow holes occur in gas cutting, the surface properties deteriorate, so the cut surface has to be touched up and the productivity is lowered. To suppress blow holes, reducing the cutting speed is effective to a certain extent, but this also lowers the productivity. However, in a steel containing a significant amount of Cr like the present invention steel, even if reducing the cutting speed, a good cut surface is difficult to obtain.

The inventors discovered that in order to secure a sufficient gas cutting property by acetylene gas in steel containing Cr-Cu-Ni-Mo-Sb, that is, a certain level of cutting speed, simultaneously with suppressing the blow holes, adding the deoxidation elements of Si and Al and reducing the N in the steel to the maximum extent alone are not sufficient and that there is an optimal balance of Si and Al. That is, the inventors discovered that a good cut surface can be obtained in the range of Si: 0.01

to 0.5% and Al: 0.005 to 0.5%.

Next, the reasons for limitation of the chemical composition of the steel of the present invention will be explained in detail.

[Chemical Composition]

First, the reasons for limiting the chemical composition of the steel used for the gas contact surface of a passage of exhaust gas, that is, steel welded together by an austenitic welding material or the steel of the surface part of a double-layer steel welded together by an austenitic welding material will be explained below.

C is preferably as small an amount as possible from the viewpoint of the wear resistance of the exhaust gas duct environment, but to secure the strength, addition of 0.001% or more is necessary, so the lower limit was made 0.001%. If over 0.2%, the wear resistance, cold workability, and weldability are impaired, so 0.001 to 0.2% was made the range of limitation.

In particular, when workability is sought, 0.01 to 0.06% is preferable. Further, when using a ferritic welding material, to secure a good welding constructability, 0.002 to 0.05% is preferable.

Cu has to be added to suppress local wear together with Ni, (Mo, W, or Mo+W), and Sb of 0.1% or more. If added over 1%, an excessive rise in strength and a drop in the manufacturability and cold workability are induced, so 0.1 to 1% is made the range of limitation. Preferably, addition of 0.2 to 0.5% gives an excellent balance of cold workability and wear resistance.

Ni is added to suppress the local wear together with Cu, (Mo, W, or Mo+W), and Sb of 0.01% or more, but the effect is sufficient at 1%, so 0.01 to 1% is made the range of limitation. However, in the case of a steel for an exhaust gas duct, the effect of suppression of local wear is sufficient at 0.5%, so 0.01 to 0.5% is made the range of limitation.

Cr is added to secure wear resistance in an amount of 4.0% or more. Even if added over 9.0%, the wear resistance is saturated, so 4.0 to 9.0% was made the range of limitation. Due to the effect of composite addition of 4.0 to 9.0% Cr-Cu-Ni-Sb-(Mo, W, or Mo+W), the wear resistance is remarkably improved compared with a system of sole addition of 4.0 to 9.0% of Cr.

Further, due to the effect of composite addition of 4.0 to 6.0%Cr-Cu-Ni-Sb, the wear resistance is remarkably improved compared with a system of sole addition of 4.0 to 6.0% Cr.

Note that if over 6.0%, even if limiting the Si, the gas cutting property by acetylene or another heat absorbing gas falls and even if lowering the cutting speed, a sufficient cut surface quality cannot be obtained, so the range of limitation is preferably made 4.0 to 6.0%. If considering the workability, gas cutting property, and wear resistance, 4.5 to 5.5% is more preferable.

Sb is added for the purpose of suppressing the local wear together with the Cu, Ni, or (Mo, W, or Mo+W) of 0.01% or more, but even if added over 0.2%, the effect is saturated, so 0.01 to 0.2% was made the range of limitation. From the viewpoint of the hot workability, 0.05 to 0.15% is preferable.

Mo and W are added for the purpose of suppressing the local wear, alone or together, together with Cu, Ni, and Sb of 0.005% or more, but if added over 0.5%, conversely the weldability or wear resistance is inhibited, so 0.005 to 0.5% was made the range of limitation. From the viewpoint of the wear resistance, economy, and weldability, 0.01 to 0.1% is preferable.

The rest of the ingredients are as follows:

Si, if added for deoxidation in an amount of 0.01% or more, reduces the gas ingredients and reduces the blow holes, so is an essential element for securing gas cutting property, but if over 0.5%, the heat affected

zone (HAZ) deteriorates in toughness, so 0.01 to 0.5% was made the range of limitation. To achieve both wear resistance and good gas cutting property, addition of 0.01 to 0.3% is preferable. When considering the steel manufacturability, weldability, etc., 0.1 to 0.3% is more preferable.

Mn is added for securing the steel strength and for deoxidation in an amount of 0.1% or more, but excessive addition causes excessive strength and impairs the cold workability, so 0.1 to 2% was made the range of limitation.

P is an impurity element. If over 0.05%, the weldability and wear resistance fall, so 0.05% or less was made the range of limitation. Note that the smaller the amount of P, the better, so 0.02% or less is preferable. Note that the lower limit value includes 0%.

S is an impurity element. If over 0.02%, the lamellar tear resistance falls, so the amount was limited to 0.02% or less. On the other hand, if S becomes less than 0.005%, the wear resistance falls, so the amount was limited to 0.005 to 0.02%. If considering the balance of the wear resistance and toughness, 0.005 to 0.015% is preferable.

Al is added as a deoxidation element in an amount of 0.005% or more. Along with the increase of Al, the wear resistance is improved, but excessive addition impairs the gas cutting property, so 0.005 to 0.5% was made the range of limitation. To secure a sufficient good gas cutting property, 0.005 to less than 0.03% is preferable.

If N is over 0.008%, it not only increases the number of blow holes formed at the time of gas cutting and lowers the gas cutting property, but also reduces the toughness, so the upper limit was made 0.008%.

Above, by these basic ingredients, the steel of the present invention can exhibit an excellent wear resistance or an excellent wear resistance and gas cutting property, but by selectively adding the following

elements, a greater effect can be expected.

Ti is added in accordance with need in an amount of 0.002% or more. It has the effect of forming TiO or TiN in the steel and making the grain size of the heat affected zone during welding finer and forming ferrite in the grains so as to improve the toughness or the effect of improving the gas cutting property of Cr-Cu-Ni-(Mo, W, or Mo+W)-Sb steel. In this case, if adding it over 0.2%, the toughness deteriorates, so the range is preferably made 0.002 to 0.2%.

Nb, V, Ta, Zr, and B are elements effective for increasing the strength of the steel and are mainly included to adjust the strength in accordance with need. To express these effects, Nb is preferably contained in an amount of 0.002% or more, V in 0.005% or more, Ta in 0.005% or more, Zr in 0.005% or more, and B in 0.0002% or more.

On the other hand, if Nb is added over 0.2%, V over 0.5%, Ta over 0.5%, Zr over 0.5%, and B over 0.005%, the toughness easily remarkably degrades. Therefore, in accordance with need, when including Nb, V, Ti, Ta, Zr, or B, Nb is preferably included in an amount of 0.002 to 0.2%, V in 0.005 to 0.5%, Ti in 0.002 to 0.2%, Ta in 0.005 to 0.5%, Zr in 0.005 to 0.5%, and B in 0.0002 to 0.005%.

Mg, Ca, Y, La, and Ce are effective for control of the morphology of the inclusions and are effective for improvement of the ductility characteristics and further are effective for improvement of the HAZ toughness of the weld joint. Further, the effects of improving the local wear resistance are weak, so these are preferably included in accordance with need.

The lower limit of the contents of the different elements in the steel of the present invention are determined from the lower limit at which their effects are expressed. Mg preferably has a lower limit of 0.0001%, Ca of 0.0005%, Y of 0.0001%, La of 0.005%, and

Ce of 0.005%.

On the other hand, the upper limit are determined by when the inclusions become coarser and by whether the mechanical properties, in particular the ductility and toughness, are adversely affected. In the steel of the present invention, from this viewpoint, preferably Mg and Ca have upper limit of 0.01% and Y, La, and Ce of 0.1%.

Sn and Pb are elements effective for further improving the wear resistance and are added in accordance with need, but the effects are preferably exhibited when Sn is 0.01 to 0.3% and Pb is 0.01 to 0.3%.

Further, in addition to the added elements, if O is over 0.0040%, the number of blow holes remarkably increases, the gas cutting property falls, and touchup work of the cut surface becomes necessary, so the upper limit is preferably made 0.0040%.

Further, even if adding one or more of Co, Ti, Nb, V, Ta, Zr, B, Mg, Ca, Y, La, Ce, Sn, and Pb to the steel of the gas contact surface in accordance with need, the effect of the present invention is not lost.

Next, the reasons for limiting the chemical compositions of the steels when both of the steel used for the gas contact surface of the passage of the exhaust gas and welding material are steels of similar chemical compositions, that is, when using a welding material of a similar composition, will be explained.

The ranges of limitation and reasons for limitation when using the above mentioned austenitic welding material are similar for C, Cu, Ni, Sb, Mo, and W.

However, Cr differs in the upper limit of the range of limitation when using an austenitic welding material and when using a welding material of a similar composition.

That is, to secure wear resistance when using a welding material of a similar composition, 4.0% or more has to be added. However, if added over 6.0%, preheating and heat processing at a relatively high temperature

become essential and the welding constructability falls, so 4.0 to 6.0% was made the range of limitation. If considering the welding constructability, workability, and wear resistance, 4.0 to 5.5% is more preferable.

Further, Si, Mn, P, and S are essential ingredients when using a welding material of a similar composition. This differs from the case of use of an austenitic welding material. However, the ranges of limitation and reasons for limitation of Si, Mn, P, and S are basically the same as the case of the above austenitic welding material.

The steel of the present invention is prepared in a converter, electric furnace, or other melting furnace, secondarily refined in accordance with need in a degasification system, ladle, etc. to obtain the predetermined compositions, then the molten steel is continuously cast or cast into steel ingots, then bloomed into a steel slab.

After this, this steel slab is hot-rolled, with or without additional heating, to a hot-rolled thin steel sheet or thick steel plate and further is cold-rolled to a cold-rolled thin steel sheet or other steel sheet. In addition, it may be hot-rolled for use as sections, steel bars, wire rods, or steel tubes, or other corrosion resistant steel members in various manners.

In general, an exhaust gas duct of exhaust gas processing equipment is comprised of a welded structure of a steel, so the steel is required to have the required properties and also welding constructability. Therefore, in order to prevent selective wear of the welding metal and secure a welding constructability equivalent to carbon steel in the present invention, the alloy composition of the welding metal is important.

Use of an austenitic welding materials with more Cr, Ni, Cu, Mo, etc. effective for the wear resistance or ferritic welding materials of a low C-Cr-Cu-Ni-(Mo, W, Mo+W)-Sb system the same as the base metal are

preferable. As the austenitic welding material, known art may be used. As an austenitic stainless steel, for example, SUS309L is commonly used.

As the material of the gas contact surface of the passage of the exhaust gas, in the case of a double-layer steel, it is important that the surface layer be a wear resistant layer made of steel having the chemical composition of the present invention. From the viewpoint of the durability, a wear resistant layer of 3 mm or more is preferable. It is more preferable that rather than a double-layer steel, the entire material be a steel having a chemical composition limited by the present invention.

As the structure of the exhaust gas duct, as explained below, a water-cooled double-wall structure or an exhaust gas duct comprised of a water-cooled steel tube panel is preferable. This is because in the case of a water-cooled double-wall structure, even if the exhaust gas is a high temperature of over 300°C, the metal surface temperature of the duct becomes at most several tens of 10°C and wear due to severe molten salt corrosion (in general, occurring when the metal surface temperature is 300°C or more) can be avoided.

[Exhaust Gas Duct of Water-Cooled Double-Wall Structure]

An example of the structure of an exhaust gas duct of a water-cooled double-wall structure is shown in FIG. 3. This is a double-wall structure exhaust gas duct comprised of an inside tube 2 made of a clad steel having a surface layer of the gas contact surface having the specific composition of the present invention or a steel having the specific composition of the present invention as a base metal and a weld zone made of an austenitic welding material (for example, SUS309L) and an outside tube 1 made of carbon steel. In the figure, 3 indicates the passage of the cooling water, while 4 indicates the passage of the exhaust gas.

An example of the structure of the inside tube comprised of clad steel having steel having the specific composition of the present invention covered on a base material 6 as a wear resistant layer 5 and a weld zone 7 made of an austenitic welding material is shown in FIG. 4. Note that in FIG. 4, 8 indicates the surface contacting the exhaust gas.

The coolant preferably has a temperature of 100°C or less. As the coolant, water is preferable. The inside tube preferably has a thickness of 6 mm or more from the viewpoint of the durability, more preferably 9 to 16 mm. The method of fabrication of the inside tube may be any method such as sheet rolling, use of a steel tube, spiral working, welding, etc. In accordance with need, the surface layer of the gas contact surface may be covered by a heat resistant, abrasion resistant material of the range of limitation of the present invention.

[Exhaust Gas Duct Comprised of Water-Cooled Steel Pipe Panel]

A structural example of an exhaust gas duct comprised of the water-cooled steel tube panel is shown in FIG. 5. At the surface opposite to the surface contacting the exhaust gas (gas contact surface), a plurality of water cooling tubes 9 are usually arranged in parallel and welded to the panel. On the panel of the array of carbon steel tubes, steel sheet having a composition limited by the present invention was welded as a gas contact surface sheet by austenitic welding material. In accordance with need, the surface layer of the gas contact surface may also be covered by a heat resistant abrasion resistant material..

Next, examples of the present invention will be explained.

(Example 1)

This is an example according to the aspects of the invention of the above (4) to (7).

The steels of the alloy compositions shown in Table

1 were melted, cast, hot-rolled to a thickness of 12 mm, and heat-treated, then the hot-rolled steel sheets were used as materials.

Table 1

		Material	C	Si	Mn	P	S	Cr	Cu	Ni	Mo	W	Sb	Al	N	Ti	Others
Comp. ex.	A1	SS400	0.11	0.2	0.4	0.02	0.010	0.02	0.02	0.02	-	-	-	0.02	0.003	-	
	A2	Low alloy steel	0.1	0.3	0.5	0.01	0.010	0.6	0.30	0.20	-	-	-	0.025	0.003	0.02	
	A3	5%Cr steel	0.05	0.3	0.4	0.01	0.010	4.9	-	-	-	-	-	0.025	0.003	-	
	A4	Cu insuf.	0.03	0.2	0.4	0.01	0.010	5.1	0.02	0.10	0.10	-	0.11	0.025	0.003	-	
	A5	Ni insuf.	0.03	0.2	0.4	0.01	0.010	5.1	0.20	-	0.10	-	0.11	0.025	0.003	-	
	A6	Mo or W insuf.	0.03	0.2	0.4	0.01	0.010	5.1	0.20	0.10	-	-	0.11	0.025	0.003	-	
	A7	Sb insuf.	0.03	0.2	0.4	0.01	0.010	5.1	0.20	0.10	0.10	-	-	0.025	0.003	-	
	A8	Cr insuf.	0.03	0.2	0.4	0.01	0.010	3.5	0.20	0.10	0.10	-	0.11	0.025	0.003	-	
	A9	Cr excess	0.03	0.2	0.4	0.01	0.010	6.9	0.20	0.10	0.10	-	0.11	0.025	0.003	-	
	A10	Si excess	0.03	0.65	0.4	0.01	0.010	4.9	0.20	0.10	0.10	-	0.10	0.025	0.003	-	
Inv. ex.	B1		0.03	0.2	0.6	0.01	0.010	4.9	0.3	0.2	0.05	-	0.10	0.025	0.003	-	
	B2		0.03	0.2	0.6	0.01	0.009	4.9	0.3	0.2	-	0.05	0.10	0.025	0.003	-	
	B3		0.03	0.2	0.4	0.01	0.010	5.1	0.2	0.1	0.01	-	0.03	0.015	0.003	-	
	B4		0.03	0.2	0.6	0.01	0.010	4.9	0.3	0.2	0.05	-	0.10	0.025	0.003	-	Ca:0.0005
	B5		0.03	0.2	0.5	0.01	0.008	4.9	0.3	0.2	0.11	-	0.10	0.025	0.003	-	Sn:0.05
	B6		0.03	0.2	0.6	0.01	0.010	4.9	0.3	0.2	0.05	-	0.10	0.025	0.003	-	Pb:0.05
	B7		0.03	0.5	0.6	0.01	0.010	5.9	0.3	0.2	0.07	-	0.10	0.025	0.003	-	B:0.0010
	B8		0.03	0.2	0.6	0.01	0.011	4.8	0.3	0.2	0.05	-	0.10	0.035	0.003	-	Nb:0.015
	B9		0.03	0.2	0.6	0.01	0.010	4.9	0.3	0.2	0.09	0.02	0.10	0.025	0.003	-	V:0.005
	B10		0.03	0.2	0.9	0.01	0.010	5.9	0.3	0.2	0.05	-	0.10	0.025	0.003	-	
	B11		0.03	0.2	0.9	0.01	0.012	4.1	0.3	0.2	0.08	-	0.10	0.025	0.003	-	
	B12		0.05	0.2	0.9	0.01	0.010	4.9	0.4	0.2	0.05	-	0.10	0.025	0.003	0.015	
	B13		0.05	0.4	0.9	0.01	0.010	4.9	0.3	0.2	-	0.15	0.10	0.025	0.003	0.015	
	B14		0.05	0.2	0.9	0.01	0.010	5.1	0.3	0.1	0.01	-	0.03	0.045	0.003	0.015	
	B15		0.05	0.2	0.9	0.01	0.010	4.9	0.3	0.2	0.07	-	0.10	0.025	0.003	0.015	Ca:0.0005
	B16		0.05	0.2	0.9	0.01	0.005	5.3	0.4	0.2	0.03	-	0.10	0.025	0.003	0.015	Sn:0.05
	B17		0.05	0.5	0.9	0.01	0.011	4.9	0.3	0.2	0.05	-	0.10	0.025	0.003	0.015	Pb:0.05
	B18		0.05	0.4	0.9	0.01	0.010	4.1	0.3	0.2	0.03	-	0.10	0.020	0.003	0.015	B:0.0010
	B19		0.05	0.2	0.9	0.01	0.010	4.9	0.5	0.2	0.05	-	0.10	0.025	0.003	0.015	Nb:0.015
	B20		0.05	0.2	0.9	0.01	0.015	5.0	0.3	0.2	0.05	0.02	0.10	0.025	0.003	0.015	V:0.004
	B21		0.05	0.2	0.9	0.01	0.010	5.9	0.3	0.2	0.05	-	0.10	0.025	0.003	0.015	
	B22		0.05	0.2	0.9	0.01	0.010	4.0	0.3	0.2	0.05	-	0.10	0.025	0.003	0.015	
	B23		0.003	0.2	0.9	0.01	0.010	5.9	0.3	0.2	0.05	-	0.10	0.025	0.003	-	
	B24		0.003	0.2	0.9	0.01	0.009	4.9	0.3	0.2	-	0.05	0.10	0.025	0.003	-	
	B25		0.003	0.2	0.9	0.01	0.010	5.1	0.2	0.1	0.01	-	0.03	0.015	0.003	-	
	B26		0.002	0.2	0.9	0.01	0.010	4.9	0.3	0.2	0.05	-	0.10	0.025	0.003	-	Ca:0.0005
	B27		0.003	0.3	0.9	0.01	0.008	4.9	0.3	0.2	0.11	-	0.10	0.025	0.003	-	Sn:0.05
	B28		0.003	0.2	0.9	0.01	0.010	5.5	0.3	0.2	0.05	-	0.10	0.025	0.003	-	Pb:0.05
	B29		0.003	0.5	0.9	0.01	0.010	4.1	0.3	0.2	0.07	-	0.10	0.025	0.003	-	B: 0.0010
	B30		0.003	0.2	0.9	0.01	0.011	5.9	0.3	0.2	0.05	-	0.10	0.035	0.003	-	Nb:0.015
	B31		0.004	0.2	0.9	0.01	0.010	4.9	0.3	0.2	0.09	0.02	0.10	0.025	0.003	-	V:0.005

* Underlined figures are outside the range of the present invention.

[Wear Test: Duct Exposure Test]

A sample of a repair use test steel sheet (250 mm x 250 mm x 12 mm) was prepared. The test steel sheet was cold bent to the diameter of the inside tube. An inside tube of an exhaust gas duct of an electric furnace for steel making for steel bar was cut open to create a space in advance, then the test steel sheet was welded therein.

The welding was performed by arc-welding with a heat input of about 20 kJ/cm and a welding material of an

austenitic stainless steel (SUS309L) covered arc-welding rod. Six months later, the section of the duct where the test steel sheet was attached was cut out by gas cutting, then test pieces were quarried, acid washed, then measured for sheet thickness, in order to find the average wear rate and local maximum wear rate and evaluate the wear resistance.

[Gas Cutting Property Test]

The test samples were cut at a constant cutting speed by straight cutting (sheet thickness 16 mm) and V-groove cutting (16 mm thickness, 30°, 40°). Then the cutting workability and state of the cut surfaces for the case of using acetylene gas or the case of using powder cutting were evaluated, relative to the comparative steel A1, as VG (very good): good, G (good): cutting easy, F (fair): cutting difficult (cut surface requires touchup), and P (poor): cutting impossible.

Table 2 shows the results of the above duct explosion test. Table 3 shows the results of the gas cutting property test.

Table 2

		Material	Average rate	Maximum rate	Evaluation
Comp. ex.	A1	SS400	8.7	12.7	Poor wear resistance
	A2	Low alloy steel	4.3	7.3	Poor wear resistance
	A3	5% Cr steel	1.3	10.6	Poor wear resistance
	A4	Cu insufficient	1.0	5.9	Poor wear resistance
	A5	Ni insufficient	1.1	6.3	Poor wear resistance
	A6	Mo or W insufficient	1.4	7.1	Poor wear resistance
	A7	Sb insufficient	1.1	6.6	Poor wear resistance
	A8	Cr insufficient	3.1	10.9	Poor wear resistance
	A9	Cr excessive	0.6	1.1	Excellent
	A10	Si excessive	1.2	2.3	Excellent
Inv. ex.	B1		0.9	1.4	Excellent
	B2		0.8	1.3	Excellent
	B3		0.7	1.2	Excellent
	B4		0.7	1.1	Excellent
	B5		0.8	1.3	Excellent
	B6		0.6	0.9	Excellent
	B7		0.6	0.9	Excellent
	B8		0.9	1.4	Excellent
	B9		0.7	1.3	Excellent
	B10		0.8	1.4	Excellent
	B11		0.9	1.4	Excellent
	B12		0.7	1.3	Excellent
	B13		0.8	0.4	Excellent
	B14		0.7	1.2	Excellent
	B15		0.6	1.1	Excellent
	B16		0.6	1.1	Excellent
	B17		0.7	0.5	Excellent
	B18		0.8	0.4	Excellent
	B19		0.6	1.0	Excellent
	B20		0.7	1.0	Excellent
	B21		0.8	1.1	Excellent
	B22		0.8	1.3	Excellent
	B23		0.8	1.4	Excellent
	B24		0.9	1.4	Excellent
	B25		0.7	1.3	Excellent
	B26		0.8	0.4	Excellent
	B27		0.7	1.2	Excellent
	B28		0.6	1.1	Excellent
	B29		0.6	1.1	Excellent
	B30		0.7	0.5	Excellent
	B31		0.8	0.4	Excellent

Table 3

		Material	Straight cutting		V-groove		Overall evaluation
			Cutting work	State of cut surface	Cutting work	State of cut surface	
Comp. ex.	A1	SS400	VG	VG	VG	VG	VG
	A2	Low alloy steel	VG	VG	VG	VG	VG
	A3	5%Cr steel	G	G	G	G	G
	A4	Cu insufficient	G	G	G	G	G
	A5	Ni insufficient	G	G	G	G	G
	A6	Mo or W insufficient	G	G	G	G	G
	A7	Sb insufficient	G	G	G	G	G
	A8	Cr insufficient	VG	G	VG	G	G
	A9	Cr excessive	P	P	F	P	P
	A10	Si excessive	P	F	F	P	P
Inv. ex.	B1		VG	VG	G	VG	G
	B2		VG	VG	G	VG	G
	B3		VG	VG	G	VG	G
	B4		VG	VG	G	VG	G
	B5		VG	VG	G	VG	G
	B6		VG	VG	G	VG	G
	B7		VG	VG	VG	VG	G
	B8		VG	VG	G	VG	G
	B9		VG	VG	G	VG	G
	B10		G	G	G	G	G
	B11		VG	VG	G	VG	G
	B12		VG	G	G	VG	G
	B13		VG	VG	G	VG	G
	B14		VG	VG	G	VG	G
	B15		VG	VG	G	VG	G
	B16		VG	G	G	VG	G
	B17		G	G	G	G	G
	B18		VG	VG	VG	VG	G
	B19		VG	VG	G	VG	G
	B20		VG	VG	G	VG	G
	B21		VG	VG	G	VG	G
	B22		VG	VG	G	VG	G
	B23		VG	VG	G	VG	G
	B24		VG	G	G	VG	G
	B25		VG	VG	G	VG	G
	B26		VG	VG	G	VG	G
	B27		VG	VG	G	VG	G
	B28		VG	G	G	VG	G
	B29		G	G	G	G	G
	B30		VG	VG	VG	VG	G
	B31		VG	VG	G	VG	G

Relative to the comparative steel A1, the order VG>G>F>P stands.

The comparative steel A1 is the commercially

available common steel for weld structure (JIS G3141 SS400), while A2 is a low alloy steel, but both have low wear resistances. Further, A3 is a low carbon steel to which 4.9% of Cr is solely added. It has an average wear rate better than A1 and A2, but has a maximum wear rate equal to A2 etc., i.e., the effect of addition of Cr is not significant.

A4, A5, A6, and A7 contain Cr in an amount of 5.1% and have Si, Cu, Ni, Mo, and Sb compositely added, but A4 is insufficient in Cu, A5 in Ni, A6 in Mo, and A7 in Sb, so the maximum wear rate is not sufficiently suppressed.

A8 has a Cr content of a low 3.5%, so the average and maximum wear rates are not sufficiently suppressed by composite addition.

A9 contains Si, Cu, Ni, Mo, and Sb in the range of the steel composition prescribed in the present invention, but contains Cr in an amount of 6.9%, so has a gas cutting property inferior to that of the present invention steels.

Further, A10 contains Cr in an amount of 4.9% and contains Cu, Ni, Mo, and Sb in amounts in the range of steel composition prescribed in the present invention, but contains 0.65% of Si, so has a gas cutting property inferior to that of the present invention steels.

As opposed to this, the invention steels B1 to B31 are in the range of steel composition prescribed by the present invention, are excellent in wear resistance, and have a gas cutting property as good as ordinary steel (A1).

(Example 2)

This is an example of the aspects of the invention of (1) to (3) and (8) to (11), respectively. Example 3 shown next stands likewise.

The steel sheet (1000 mm x 500 mm x 12 mm) of each alloy composition shown in Table 4 was cut into two in the longitudinal direction. The two pieces were butt-welded, then the assembly was cold bend to the diameter

of an inside tube. The inside tube of an exhaust gas duct of an electric melting furnace for steel bars (site 1) and a water-cooled duct of a converter OG exhaust gas processing equipment (site 2) were cut open to form windows, where the test steel sheets were welded.

The welding was performed by arc-welding with a heat input of about 20 kJ/cm and a welding material of an austenitic stainless steel (SUS309L) covered arc-welding rod.

No preheating or later heat processing was particularly performed. In each test sample, the weldability was a sufficient, equivalent to carbon steel. Six months later, each section of the duct where a test steel sheet was attached was cut out by gas cutting, then test pieces were cut out, acid washed, then measured for sheet thickness to find the average wear rate and local maximum wear rate, and the wear resistance was evaluated.

Table 5 shows the results of the above duct exposure test.

Table 4

		Material	C	Si	Mn	P	S	Cr	Cu	Ni	Mo	W	Sb	Al	N	Ti	Others
Comp. ex.	A1	SS400	0.11	0.2	0.4	0.02	0.010	0.02	0.20	0.02	-	-	-	0.02	0.003	-	
	A2	Low alloy steel	0.1	0.3	0.5	0.01	0.010	<u>0.6</u>	0.30	0.20	-	-	-	0.025	0.003	0.02	
	A3	5% Cr steel	0.05	0.3	0.4	0.01	0.010	4.9	-	-	-	-	-	0.025	0.003	-	
	A4	Cu insufficient	0.03	0.2	0.4	0.01	0.100	5.1	<u>0.02</u>	0.10	0.10	-	0.11	0.025	0.003	-	
	A5	Ni insufficient	0.03	0.2	0.4	0.01	0.100	5.1	0.20	<u>-</u>	0.10	-	0.11	0.025	0.003	-	
	A6	Mo or W insufficient	0.03	0.2	0.4	0.01	0.100	5.1	0.20	0.10	<u>-</u>	<u>-</u>	0.11	0.025	0.003	-	
	A7	Sb insufficient	0.03	0.2	0.4	0.01	0.100	5.1	0.20	0.10	0.10	-	<u>-</u>	0.025	0.003	-	Sn: 0.04
	A8	Cr insufficient	0.03	0.2	0.4	0.01	0.100	<u>3.0</u>	0.20	0.10	0.10	-	0.11	0.025	0.003	-	
Inv. ex.	B1		0.03	0.2	0.4	0.01	0.010	4.1	0.5	0.3	0.05	-	0.10	0.025	0.003	-	
	B2		0.03	0.2	0.4	0.01	0.009	5.1	0.3	0.2	-	0.05	0.10	0.025	0.003	-	
	B3		0.03	0.2	0.4	0.01	0.009	5.1	0.2	0.1	0.05	-	0.11	0.015	0.003	-	
	B4		0.03	0.2	0.4	0.01	0.010	7.1	0.3	0.2	0.05	-	0.10	0.025	0.003	-	
	B5		0.05	0.2	0.4	0.01	0.010	8.9	0.3	0.2	0.05	-	0.10	0.025	0.003	0.015	

* Underlined figures are outside the range of the present invention.

Table 5

		Material	Average rate	Maximum rate	Evaluation
Comp. ex.	A1	SS400	8.7	12.7	Poor wear resistance
	A2	Low alloy steel	4.3	7.3	Poor wear resistance
	A3	5% Cr steel	1.3	10.6	Poor wear resistance
	A4	Cu insufficient	1.0	5.9	Poor wear resistance
	A5	Ni insufficient	1.1	6.3	Poor wear resistance
	A6	Mo or W insufficient	1.4	7.1	Poor wear resistance
	A7	Sb insufficient	1.1	6.6	Poor wear resistance
	A8	Cr insufficient	3.1	10.9	Poor wear resistance
Inv. ex.	B1		3.9	4.9	Excellent
	B2		1.2	1.6	Excellent
	B3		1.2	1.5	Excellent
	B4		0.6	1.3	Excellent
	B5		0.4	1.1	Excellent

The comparative example A1 is a commercially available common steel for welded structure (JIS G3141, SS400), while A2 is a low alloy steel. Both have low wear resistances. Further, A3 is a low carbon steel in which 4.9% Cr is solely added. The average wear rate is better than A1 and A2, but the maximum wear rate is equal to A2, so the effect of addition of Cr is not significant.

Further, A4, A5, A6, and A7 contain Cr in an amount of 5.1% and further have Si, Cu, Ni, Mo, and Sb compositely added, but A4 is insufficient in Cu, A5 in Ni, A6 in Mo, and A7 in Sb, so that maximum wear rate is not sufficiently suppressed.

Further, A8 has a Cr content of a low 3.0%, so the average and maximum wear rates are not sufficiently suppressed by the composite addition.

As opposed to this, it is learned that the invention examples B1 to B5 are in the range of the steel composition prescribed in the present invention and are excellent in wear resistance.

(Example 3)

The steel sheet (300 mm x 300 mm x 12 mm) of each alloy composition shown in Table 6 was butt-welded by a

weld ferritic alloy welding rod and investigated for welding constructability and weld crack susceptibility.

The welding rod was arranged to the alloy composition shown in Table 7 so that the composition in the welding metal of the Cr-Cu-Ni-Mo-Sb important for securing the wear resistance becomes the same extent as the chemical composition of the steel sheet. The welding was performed by arc-welding with an input heat of about 20 kJ/cm.

Table 6

		C	Si	Mn	P	S	Cr	Cu	Ni	Mo	W	Sb	Al	N	Ti	Others
Comp. ex.	C1	0.05	0.3	0.4	0.01	0.010	3.5	0.50	0.30	0.05	-	0.10	0.025	0.003	-	
	C2	0.03	0.2	0.4	0.01	0.100	6.5	0.20	0.10	0.10	-	0.11	0.025	0.003	-	
Inv. ex.	C3	0.03	0.2	0.4	0.01	0.010	4.1	0.5	0.3	0.05	-	0.10	0.025	0.003	-	
	C4	0.01	0.2	0.4	0.01	0.010	5.9	0.3	0.2	0.05	-	0.10	0.025	0.003	0.015	

Table 7

	Welding metal	C	Si	Mn	P	S	Cr	Cu	Ni	Mo	W	Sb
Comp. ex.	WM1	0.07	0.2	0.6	0.01	0.011	3.6	0.50	0.30	0.05	-	0.10
	WM2	0.03	0.2	0.4	0.01	0.100	6.5	0.20	0.10	0.10	-	0.11
Inv. ex.	WM3	0.03	0.2	0.4	0.01	0.010	4.1	0.5	0.3	0.05	-	0.10
	WM4	0.01	0.2	0.4	0.01	0.010	5.9	0.3	0.2	0.05	-	0.10

As a result, in the weld joint obtained by butt-welding of the comparative example steel sheet C2 as a base metal with a welding rod of a composition of the welding metal WM2 (hereinafter referred to as the weld joint C2), low temperature cracking was observed in the welding metal.

On the other hand, in weld joints having the steel sheets C1, C3, and C4 as base metals and having WM1, WM3, and WM4 as welding metals (hereinafter referred to as the weld joints C1, C3, and C4), the welding constructability and crack susceptibility were good.

Next, each of the joints other than the weld joint C2, that is, the weld joints C1, C3, and C4, in same way as Example 1, was attached to the gas contact surface of an exhaust gas double-wall water-cooled duct of a steel refining electric furnace. Six months later, the section of the duct where the test steel sheet was attached was cut out by gas cutting, then test pieces were cut out, acid washed, then measured for sheet thickness to find the average wear rate and local maximum wear rate, and the wear resistance was evaluated.

Table 8 shows the results of the above duct exposure test.

Table 8

	Welding metal	Base metal	Base metal		Welding metal		Evaluation
			Average rate	Max. rate	Average rate	Max. rate	
Comp. ex.	WM1	C1	4.3	7.9	4.8	9.3	Poor wear resistance
	WM2	C2	–	–	–	–	Weld cracks, no data
Inv. ex.	WM3	C3	3.9	4.9	3.9	4.9	Excellent
	WM4	C4	0.4	1.1	0.4	1.1	Excellent

The comparative example weld joint C1 has less Cr in both the base metal and welding metal than the lower limit of Cr prescribed in (3), so it is learned that the wear resistance is inferior to that of the invention examples C3 and C4. Further, as explained above, the comparative example weld joint C2 has Cr in both the base

metal and welding metal over the upper limit of Cr prescribed in the aspect of the invention of (3), so it is learned that sufficient weldability cannot be obtained.

From the above results, it is learned that if both the base metal and welding metal have Cr in the range prescribed in the aspect of the invention of (10), even if using a ferritic welding material, both a excellent wear resistance and welding constructability can be achieved along with gas cutting property.

INDUSTRIAL APPLICABILITY

The steel of the present invention and the exhaust gas duct comprised using the steel, when used for example for a duct, heat exchanger, electric dust collector, cooling tower, smokestack, etc. in an exhaust gas processing system of a steelmaking electric furnace or steelmaking converter, exhaust gas processing system of an ash melting furnace, or exhaust gas processing system of an incineration equipment of garbage, sludge, etc., extends the lifetime of the equipment due to its excellent durability, enables continuation of the same maintenance and management and same repair methods as with conventional carbon steel, and therefore is extremely high in industrial value.